Fishery Data Series No. 92-50

Harvest Distribution, Age Composition, Density, and Abundance of Razor Clams Along the Eastern Beaches of Cook Inlet, 1991

by

David E. Athons

November 1992

Alaska Department of Fish and Game

Division of Sport Fish

FISHERY DATA SERIES NO. 92-50

HARVEST DISTRIBUTION, AGE COMPOSITION, DENSITY AND ABUNDANCE OF RAZOR CLAMS ALONG THE EASTERN BEACHES OF COOK INLET, 1991

By

David E. Athons

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

November 1992

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Population studies of the Pacific razor clam *Siliqua patula* were conducted on the western beaches of the Kenai Peninsula during the summers of 1990 and 1991. Aerial surveys used to apportion digger effort by beach revealed that the two most popular beaches of Clam Gulch and Ninilchik received 35% and 43%, respectively, of the overall effort during 1991. During both 1990 and 1991, age-3 clams provided the largest proportion (27.3% and 57.3%, respectively) of the harvest on Ninilchik Beach. Age-8 clams contributed the largest proportion (36.8% and 32.3%, respectively) of the Clam Gulch harvest during those years. Total clam abundance on Clam Gulch beach as estimated by on-site surveys in 1990 was 3,092,000 clams. Clam abundance on Clam Gulch beach remained stable since 1989, annual exploitation was low (7.3%), and recruitment of age-3 clams was low (2.7% and 5.2% in 1989 and 1990, respectively). Population estimates from catch-at-age analysis revealed increased abundance of age-4 and older clams from population levels during the mid-1980s. However, clam abundance in 1989 and 1990 on Clam Gulch beach as estimated from catch-at-age analysis was nearly 7 million clams; greater than double the on-site survey estimates. The two estimates of clam abundance in 1988 were similar (approximately 6 million clams). Recent-year population estimates from catch-at-age analysis are probably unreliable and will likely decrease with additional years' data. Estimated clam density on Ninilchik beach in 1991 (1.595 clams/m^2) was greater than the 1990 estimate (1.020 clams/m^2). This increase in abundance is likely due to high levels of recruitment of age-3 clams. Estimated exploitation on Ninilchik beach during 1991 using a preliminary harvest estimate was 17.6%.

KEY WORDS: Cook Inlet, razor clam, *Siliqua patula*, harvest, participation, population estimate, exploitation, density estimate, catch-at-age analysis.

INTRODUCTION

Kenai Peninsula beaches along the east side of Cook Inlet provide for the largest sport fishery for the Pacific razor clam *Siliqua patula* (Dixon) in Alaska. This fishery is confined primarily to an 80.4 km (50 mile) section of beach bounded by the Kasilof River to the north and the Anchor River to the south (Figure 1). The Alaska Department of Fish and Game (ADF&G) began monitoring this clam population in 1965 following the 1964 earthquake which caused subsidence of beaches in the Cook Inlet area (Nelson *Unpublished*).

The eastside Cook Inlet beach was divided into six separate beach areas for study purposes. Initial studies included creel surveys, digger distribution surveys and age at length analysis (Nelson *Unpublished*). Beginning in 1977, harvest and participation estimates have been obtained from the annual Statewide Harvest Study (Mills 1979-1991).

Marked increases in both harvest and participation occurred in the late 1960s and early 1970s. Since 1973, increases have been gradual and participation has averaged 28,760 digger-days annually with a high of 32,500 days in 1986. Annual harvests since that time have averaged 936,371 clams with the greatest harvest being 1,171,000 which occurred in 1988 (Figure 2).

Although there have been only moderate increases in harvest since 1977, use patterns have changed dramatically. Clam Gulch and Ninilchik beaches have been targeted for recent study as they have consistently provided the greatest proportion of the total harvest. Clam Gulch contributed more than 70% of the harvest on eastside beaches in the late 1970s. Digger effort shifted in the 1980s and Ninilchik beach has produced the greatest proportion of the overall harvest since 1986 (Figure 3). This shift is probably due to a decline in mean size of clams available for harvest at Clam Gulch and increasing numbers of clams of a larger size on Ninilchik beach. Growth rates increase incrementally from the northern to the more southern beaches.

Regulations governing this fishery are minimal. The daily bag limit is the first 60 clams dug and an Alaska sport fishing license is required for all persons 16 years of age or older. While the fishery appears to be well within sustainable bounds at the present time (Nelson *Unpublished*), large harvests combined with shifts in digger concentrations led managers to seek methodology which would forecast the effect of harvest on future abundance.

In 1987, Dr. Terrance Quinn with the University of Alaska, Juneau was contracted by ADF&G to further analyze existing data and to develop methods to estimate abundance. Clam density was directly estimated by pumping sample plots to census abundance within a known area. Sample plots were selected with a stratified-random design and density results applied to the beach area to estimate abundance. Age-specific harvest data were modeled using catch-at-age analysis to develop estimates of abundance-at-age and exploitable abundance-at-age. This work was conducted in conjunction with a graduate research project and is documented in a masters thesis by Szarzi (1991) which includes data analysis for 1988 and 1989.

The objectives of this report are to present the 1990 and 1991 stock assessment data and then to update the catch-at-age analysis. Readers may note small discrepancies in harvest apportionment tables between this report

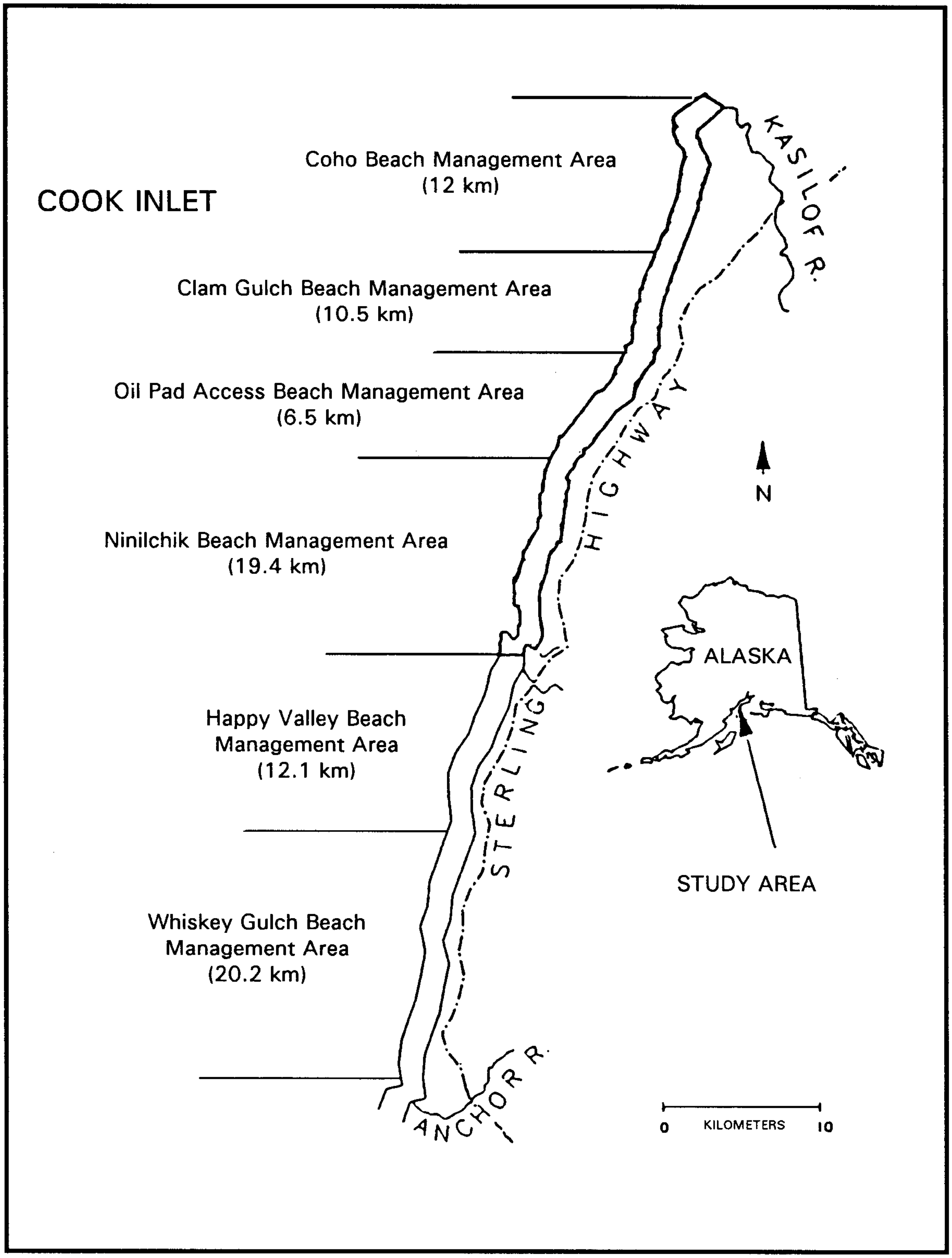

Figure 1. Eastside beaches, Cook Inlet, Alaska.

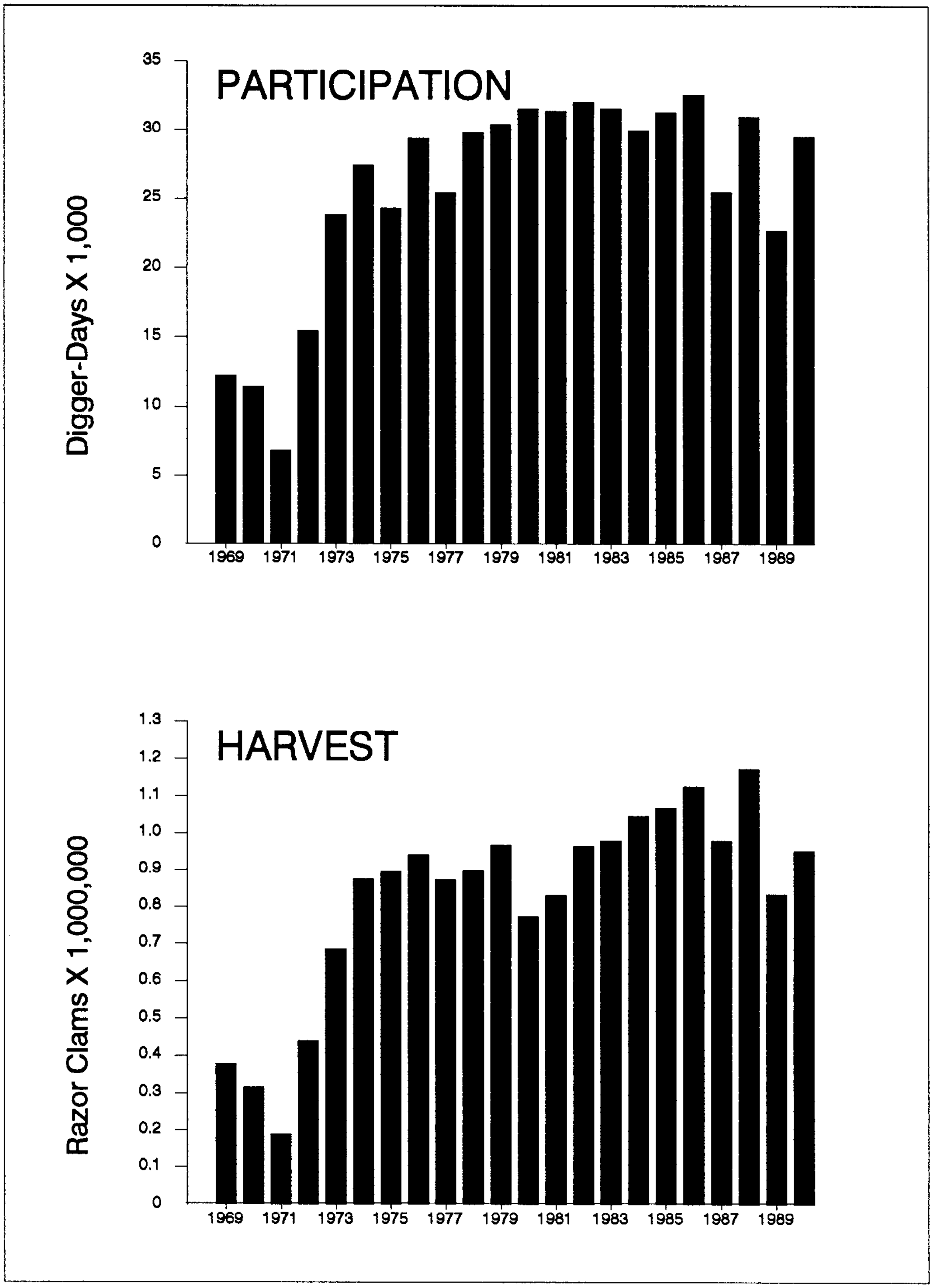

Figure 2. Historical harvest and participation in the recreational razor clam fishery on the Kenai Peninsula eastside beaches, 1969-1990.

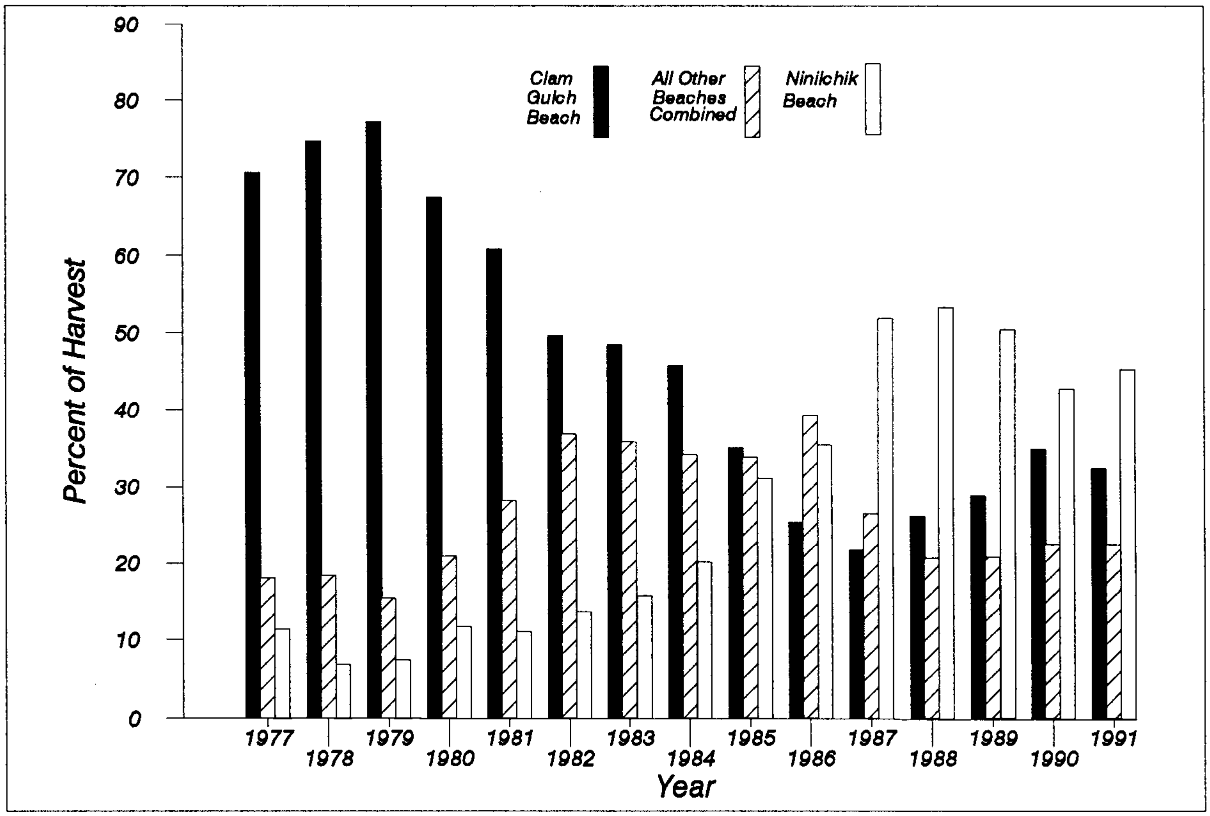

Figure 3. Historical proportions of razor clam harvest by beach area in the recreational fishery on the Kenai Peninsula, 1977-1991.

and Szarzi's thesis. These changes resulted from this researcher returning to historic data and correcting errors in the calculation of digger distributions by beach.

The 1991 project had three operational objectives:

1. estimate the proportion of digger effort directed toward razor clams by beach area,

2. estimate the age composition and mean length-at-age of razor clams by beach area, and

3. estimate the population density of razor clams on a section of the Ninilchik Beach.

The first two objectives permitted estimates of harvest by beach by age which were used to update the catch-at-age analysis for Clam Gulch beach.

METHODS

Study Design

Szarzi (1991) documented a 2-year study of razor clams on the Kenai Peninsula and provided two major products. First, estimates of mean density (number per m^2) and total population abundance were documented. These data provided real time stock assessment, including the basis for estimating exploitation. Second, age and length composition by beach were presented which provided the basis for catch-at-age analysis for Clam Gulch beach. The database required for the catch-at-age analysis included harvest and age compositions by beach area, auxiliary information on fishing mortality, and initial estimates of natural mortality (Szarzi 1991, Deriso et al. 1985, 1989).

To develop this database, the stock assessment program was designed to estimate three parameters. First, counts of diggers were conducted from aerial surveys to apportion digger effort by beach. These data were then applied to estimates of total harvest provided by Mills (1979-1991) to estimate harvest by beach. Second, beach-specific sampling was conducted to estimate age and length composition of the clam population by beach. These data were then applied to estimates of harvest by beach to estimate age-specific harvest by beach. Third, surveys were conducted to estimate clam density by beach. These data were applied to estimates of beach area to estimate total abundance by beach. Estimates of abundance and estimates of harvest provided estimates of fishing mortality. Finally, these three parameters provided the input into the catch-at-age analysis.

Estimation of Digger Effort and Harvest by Beach

The estimates of proportion of diggers on each beach was stratified by tidal stage and the total estimate of relative effort weighted by the frequency of tides within each stage. Relative effort was estimated as a proportion of diggers by beach adjusted by a harvest success rate for each beach (Szarzi 1991).

In 1990, 12 flights were conducted and 96% of the diggers in these samples were observed when the tide was a -1.0 ft or lower. Based on this observation, two tidal stage strata were defined: (1) high-low tides which were -1.0 ft to -3.0 ft, and (2) low-low tides which were less than -3.0 ft. The Ninilchik Bar is a small offshore island which is accessible to diggers in waders when the tide level is lower than -3.0 ft. Few diggers were present on Ninilchik Bar in 1990 at tides above -3.0 ft, but up to 18% of the entire population of diggers along the eastern Cook Inlet beaches were counted on the bar at lower tides. In 1991, 24 tides during May and August were between -1.0 ft and -3.0 ft and 21 tides were lower than -3.0 ft. Over the summer, a total of 12 flights were scheduled, stratified equally by tide stage. Due to weather, only 10 flights were completed: 4 in the strata between -1.0 ft and -3.0 ft, and 6 in the strata lower than -3.0 ft. Estimates of the proportion of diggers by beach and their variances for 1990 were used to calculate expected levels of precision for 1991. The precision expected with a minimum sample size of 10 flights was within 30 percentage points 95% of the time for Clam Gulch and Ninilchik beaches which represented over 50% of the effort.

Flights which could not be made due to weather were rescheduled on a similar tide level. The aerial surveys originated at Anchor River within $\pm$ 15 minutes of low water at Deep Creek and proceeded north. As it was impossible to distinguish diggers from non-diggers, all persons associated with digging activity were included in the count including those traveling along the beach on all-terrain vehicles. Persons in highway vehicles and those associated with commercial fishing activities were not included.

Counts of diggers were collected as a stratified, two-stage sampling design with high-low tides and low-low tides as the two strata, flights as the primary units, and diggers as the secondary units. Primary units (flights) were not chosen randomly, but were spread out through time in a natural progression. During each flight, diggers were counted and the location by beach of every digger was recorded. Location (beach) was an attribute in this situation, not a sampling stage. The fraction used for expansion to estimate harvest by beach was the fraction of diggers on a certain beach. The multinomial proportions were calculated and combined across the primary units and then the strata.

Success rate for diggers varied by beach. Thus, equal numbers of diggers counted on different beaches may not result in the same number of clams harvested. To account for this, a harvest success rate (I_b) of either 1.0 or 0.5 was assigned to each beach based on historical information. Digger counts for each beach were multiplied by the harvest success rate to give adjusted digger counts:

$$d_{tbk} = I_b A_{tbk} \quad , \tag{1}$$

where:

d_{tbk} = the adjusted digger count,

I_b = the harvest success rate for beach b, and

A_{tbk} = the number of diggers counted during flight k on beach b in tidal strata t.

The relative effort on each beach in each flight was estimated by:

$$r_{tbk} = \frac{d_{tbk}}{d_{tk}}, \tag{2}$$

where:

r_{tbk} = the relative effort in flight k on beach b in tidal strata t, and

d_{tk} = the total adjusted digger count for flight k in tidal strata t,

$= \sum_{b=1}^{n} d_{tbk}$, and

n = the total number of beaches.

Average relative effort for beach b in tidal strata t ($\bar{r}_{tb}$) was calculated, incorporating the sample weights (w_{tk}) that adjust the proportions for different numbers of diggers during different flights.

$$\bar{r}_{tb} = \frac{\sum_{k=1}^{c_t} w_{tk}\hat{r}_{tbk}}{c_t}, \tag{3}$$

where:

w_{tk} = the sample weight for flight k in tidal strata t,

$= \frac{d_{tk}}{\bar{d}_t}$,

$\bar{d}_t = \frac{\sum_{k=1}^{c_t} d_{tk}}{c_t}$, and

c_t = the number of flights taken in tidal strata t.

Average relative effort for beach b ($\bar{r}_b$) was then calculated, incorporating the sample weights (w_t) that adjust the proportions for different number of tides in each tidal strata:

$$\bar{r}_b = \sum_{t=1}^{2} W_t \bar{r}_{tb}, \tag{4}$$

where:

W_t = the sample weight for tidal strata t,

$$= \frac{m_t}{\sum_{t=1}^{2} m_t}, \text{ and}$$

m_t = the number of tides in tidal strata t.

The estimated harvest by beach (H_b) and its variance were:

$$\hat{H}_b = \bar{r}_b \hat{H} , \tag{5}$$

where:

$\hat{H}$ = the estimate of harvest for razor clams between Kasilof and Anchor Point from the statewide postal harvest survey (Mills 1990, 1991), and

$$\hat{V}[\hat{H}_b] = \left\{ \bar{r}_b^2 \hat{V}[\hat{H}] + \hat{H}^2 \hat{V}[\bar{r}_b] - \hat{V}[\hat{H}]\hat{V}[\bar{r}_b] \right\} , \tag{6}$$

where:

$V[\hat{H}]$ = the variance of the statewide postal survey estimate (from Michael Mills, Alaska Department of Fish and Game, Anchorage, personal communication), and

$$\hat{V}[\bar{r}_b] = \sum_{t=1}^{2} W_t^2 \hat{V}[\bar{r}_{tb}] . \tag{7}$$

There was a good chance that the number of diggers was directly related to the size of the minus tide. Since heights of tides run in cycles and selection of flights is not random, but "pseudo-systematic", numbers of diggers (sample weights) were probably cyclic, and therefore, a systematic variance equation (Wolter 1985) was used to estimate the variance of r_{tb}:

$$\hat{V}[\bar{r}_{tb}] = \left\{1 - \frac{c_t}{m_t}\right\} \left\{\frac{\sum_{k=2}^{c_t} \left(w_{tbk}r_{tbk} - w_{tb(k-1)}r_{tb(k-1)}\right)^2}{2c_t^2(c_t-1)}\right\} . \tag{8}$$

<u>Estimation of Age and Length Composition and Age-Specific Harvest by Beach</u>

Age composition has been estimated since 1977 on the eastside beaches (Nelson *Unpublished*). Szarzi (1991) recommended that a minimum of 300 clams needed to be sampled per beach in order to estimate age composition and mean length-at-age for the major age classes with adequate precision (within 5 percentage points of the true value 90% of the time) for use in the catch-age analysis.

Age and size composition of the harvest were estimated from clams that were hand dug from the beach areas in a manner and at locations within that area that would simulate an average clam digger. All clams dug were retained regardless of size or condition in compliance with state regulation.

Samples were dug on that portion of the Clam Gulch beach that lies between 0.4 km (0.25 mi) south to 0.8 km (0.5 mi) north of the access road. The Oil Pad Access beach sample was divided with half of the specimens being obtained from the northern end and the other half obtained from the southern end of the beach. Half of the Ninilchik beach sample was dug on that area of the Beach lying south of the Ninilchik River including the Ninilchik bar. Clams which were dug on the bar were aged separately from those dug on the main beach. The second half of the Ninilchik sample was dug on that section of the beach which lies north of the Ninilchik River and was also aged separately. Additionally, small samples were obtained from Deep Creek and Cohoe beach with results included in the long term database but not incorporated into this report.

In 1991, more than 300 clams were dug from the Clam Gulch, Oil Pad Access, and Ninilchik beaches with a target of 300 usable specimens. Sample processing included removing the body from the shell, separating the two halves of the shell, and retaining one half for analysis. Shells were soaked in a 50% household bleach solution until most of the periostracum had been removed but the heavy layers which lie along the annuli remained. The bleach solution was then poured off and the shells allowed to dry for aging and measuring. Aging of each individual specimen was accomplished as described by Nelson (*Unpublished*). Overall length and length at last annulus were measured using Mitutoyo Digimatic Calipers® and input directly into a Lotus spreadsheet.

To estimate the harvest by age class, the proportion of clams in age class i on beach b (p_{ib}) was estimated by:

$$\hat{p}_{ib} = \frac{n_{ib}}{n_{tb}} , \tag{9}$$

where:

n_{ib} = the number of clams sampled in age class i from beach b, and

n_{tb} = the total number of clams in the sample from beach b.

The variance of the proportion was estimated by:

$$\hat{V}[\hat{p}_{ib}] = \frac{\hat{p}_{ib}(1-\hat{p}_{ib})}{n_{tb} - 1} . \tag{10}$$

Harvest by age class for beach b was estimated by:

$$\hat{H}_{ib} = \hat{p}_{ib}\hat{H}_b \ , \tag{11}$$

with variance:

$$\hat{V}[\hat{H}_{ib}] = \hat{p}_{ib}\hat{V}[\hat{H}_b] + \hat{H}_b\hat{V}[\hat{p}_{ib}] - \hat{V}[\hat{p}_{ib}]\hat{V}[\hat{H}_b]. \tag{12}$$

Estimation of Mean Density, Abundance, and Fishing Mortality

Mean density and population estimates have been made on Ninilchik beach since 1989. Variability has proved to be higher on this beach than at Clam Gulch (Szarzi 1991), and in 1991 a third estimate was made.

The Ninilchik study area was a 5.8 km (3.6 mi) section of beach divided into two sections: a 4.2 km (2.6 mi) section lying north of Ninilchik River and a 1.6 km (1.0 mi) section south of the river. The southern area was further divided into three equal sections and the northern into five equal sections. Sample design called for sampling at least one transect in each section and, as 2 additional days were available for sampling, two randomly selected northern sections contained an additional transect.

Transect locations were randomly chosen within each beach section. Transect locations for the population density estimate on the beach lying north of the Ninilchik River were located by starting where the beach access road enters the beach at Lehmans Point and proceeding south the selected distance and stopping prior to traveling an additional 0.16 km (0.1 mi). The sampling therefore took place within the 0.16 km site location selected. Transect locations on the beach lying south of the Ninilchik River were located by starting at the pilings located at the high tide line approximately 182 m (200 yards) south of the Ninilchik River and proceeding south in the same manner. Transects began at the gravel edge located high up on the beach and extended out to the extreme low tide line. The first sampling location was chosen randomly in the first 15.2 m (50 ft) and samples were taken systematically every 15.2 m thereafter as far out as the tide would allow.

At least two and up to seven 0.5 m^2 samples were taken at each sampling location. Transects extended out a minimum of 167 m (550 ft) and a maximum of 467 m (1,500 ft). These two sampling variables were dependent on the tidal range, the rate at which the tide fell, and the beach substrate. In 1990, many transects made on the smaller tides did not extend into the lower beach locations 900 feet out, where higher densities were more likely. Thus, some higher density locations were sampled as few as two or three times. It was anticipated that in 1991, as most samples were carried out on tides of -4.0 or lower, sample sizes would increase in the more offshore locations. In the three transects south of the Ninilchik River, transects extended out to 395 m to 456 m (1,300 ft to 1,500 ft) and from 19 to 30 tidal heights were sampled. In the transects north of the Ninilchik River, transects extended out to 167 m to 228 m (550 ft to 750 ft) and from 11 to 13 locations were sampled. The beach area north of the river had a steeper gradient than the area south of the river, and less beach area was exposed than anticipated, although sampling occurred during lower tides than in 1990.

Sampling equipment consisted of a 4-cycle Honda pump with 30 meters of cotton firehose on the outlet side and 6 meters of plastic hosing on the inlet side. Midway through the season, the inlet hose was replaced with 12 meters of hose which increased sampling flexibility. The outlet hose had a metal tube or "wand" attached to direct the flow of water into the substrate enclosed by a 0.5 m^2 sampling ring (Figure 4). This sampling equipment is described in detail by Szarzi (1991).

Samples were collected as described by Szarzi (1991). To collect a sample, the wand was repeatedly inserted into the substrate inside the sample ring as far as the wand would penetrate. The stream of water loosened the substrate enclosed in the ring such that all clams within the ring were flushed to the surface. The sampling was considered complete when the entire area was fluid and no clams had surfaced for approximately 1 minute. A hand-held net with 2 mm mesh was used to strain the loosened substrate in search of small clams not readily visible. All clams were measured and then released. An attempt was made to collect between two and seven samples at each sample location prior to following the tide out 15.2 m to the next sample location. Due to rapidly dropping tides, there were times when entire sample locations were bypassed on the ebb tide. A marker was left in the sand at each sample location where less than seven samples had been obtained with as many of the remaining samples as possible being collected as the incoming tide flooded the beach. Distance from the gravel's edge along with the length of each clam from each sample pumped were recorded in a field notebook and later entered into a data file.

The mean density of clams on the Ninilchik beach from 4.2 km (2.6 mi) north of Ninilchik River to 1.6 km (1 mi) south was estimated using a three-stage design. The density estimate was for clams larger than 80 mm which are considered exploitable.

The mean density for a sample location was estimated by:

$$\bar{y}_{ij} = \frac{\sum_{k=1}^{n_{ij}} y_{ijk}}{n_{ij}}, \tag{13}$$

where:

$\bar{y}_{ij}$ = the mean density per 0.5 m^2 for beach section i in transect j,

y_{ijk} = the number of clams in sample k on section i in transect j, and

n_{ij} = the number of samples taken at beach section i in transect j.

The variance among samples was estimated by:

$$s^2_{ij} = \frac{\sum_{k=1}^{n_{ij}} (y_{ijk} - \bar{y}_{ij})^2}{n_{ij}(n_{ij}-1)}. \tag{14}$$

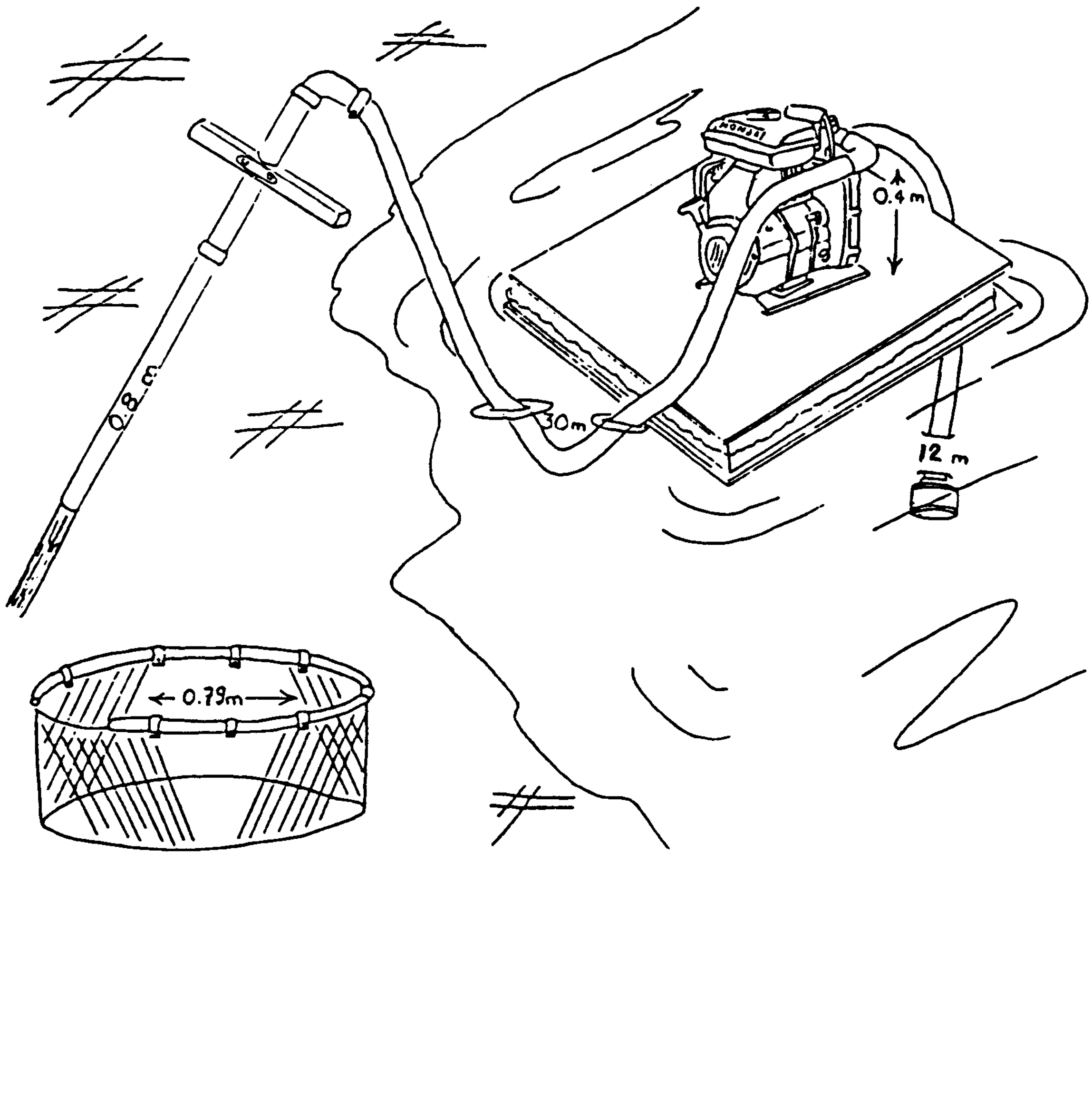

Figure 4. Sampling ring and pumping apparatus used for razor clam field sampling.

The mean of all transects for beach section i was estimated by:

$$\bar{y}_i = \frac{\sum_{j=1}^{n_i} \bar{y}_{ij}}{n_i}, \tag{15}$$

where:

$\bar{y}_i$ = the mean density 0.5 m^2 for beach section i, and

n_i = the number of transects sampled in beach section i.

The variance among transects was estimated by:

$$s^2{}_i = \frac{\sum_{j=1}^{n_i} (\bar{y}_{ij} - \bar{y}_i)^2}{n_i(n_i-1)} . \tag{16}$$

The mean density per m^2 for all beach sections was estimated by:

$$\bar{y} = 2 \left[\frac{\sum_{i=1}^{n} \bar{y}_i}{n} \right] , \tag{17}$$

where:

$\bar{y}$ = the mean density per m^2 for the beach, and

n = the total number of beach sections.

Note that the samples were taken in 0.5 m^2 areas, so the mean density is multiplied by 2 to give density per m^2.

Mean density is known to increase down the beach (Szarzi 1991), and beach sections were sampled systematically with samples taken every 50 m. The variance among beach sections was, therefore, estimated by a systematic variance equation (Wolter 1985):

$$s^2 = \frac{\sum_{i=2}^{n} (\bar{y}_i - \bar{y}_{(i-1)})^2}{2n(n-1)} . \tag{18}$$

The variance of the mean density per m^2 for the beach was estimated by:

$$\hat{V}[\bar{y}] = 4 \left[s^2 + \frac{1}{n^2} \sum_{i=1}^{n} s^2{}_i + \frac{1}{n^2} \sum_{i=1}^{n} \frac{1}{n^2{}_i} \sum_{j=1}^{n_i} s^2{}_{ij} \right] . \tag{19}$$

The total area for the beach was calculated using the length of the longest transects as the width of the beach, and the population abundance of the beach was then estimated by:

$$\hat{N} = A\,\bar{y}\ , \tag{20}$$

where:

$\hat{N}$ = the abundance of clams $\geq$ 80 mm on the beach, and

A = the area of the beach in m^2 ,

and the variance was estimated by:

$$\hat{V}(\hat{N}) = A^2\hat{V}[\bar{y}]. \tag{21}$$

Annual exploitation was computed by dividing the total estimate of harvest by beach by the total estimate of abundance by beach. Survey estimates of exploitation rates were converted to instantaneous fishing mortality by solving the Baranov catch equation (Deriso et al. 1989) for fishing mortality using abundance estimates from the density samples.

Catch-at-Age Analysis

Catch-at-age analysis was performed using the CAGEAN model developed by Deriso et al. (1985, 1989) as applied by Szarzi (1991) for razor clams at Clam Gulch beach during the period 1977-1989. Inputs into the model were: (1) harvest by age for Clam Gulch beach, (2) instantaneous fishing mortality, and (3) natural mortality. Estimation of the first two parameters are described above. Natural mortality was estimated at 0.125 by Quinn and Jones (1989).

Presentation of the results from the output of CAGEAN include: (1) estimates of total abundance by age, and (2) estimates of harvestable abundance by age. Szarzi (1991) estimated that minimum length-at-recruitment into the fishery was 80 mm. CAGEAN output provided estimates of the fraction of each age class recruited to the fishery.

RESULTS

Estimation of Digger Effort and Harvest by Beach

Aerial survey counts of clam diggers on eastside beaches from 1990 and 1991 are provided in Appendix A1. Ninilchik beach contributed the largest proportion of clams to the fishery during both 1990 and 1991 with Clam Gulch providing the second largest proportion (Table 1). As harvest estimates are obtained from the Statewide Harvest Study, harvest for 1991 will not be available until the fall of 1992. Clam Gulch has historically provided the largest proportion of the harvest averaging 47.6% since 1977 (Table 2). It should be noted that prior to 1990, the effort surveys were not weighted by tidal height and in some years as few as three surveys were flown. While there has been an upward trend in harvest and participation since 1977, this increasing trend has been gradual and was most pronounced in the mid-1980s.

Table 1. Harvest and relative success rates in the Cook Inlet eastside beaches razor clam fishery, 1990 and 1991.[a]

Beach Area	Relative Proportion	Relative Success	Harvest	Standard Error	95% C.I. Lower	95% C.I. Upper	Relative Precision
1990							
Whiskey Gulch	0.0136	0.5	12,959	1,596	9,831	16,087	0.2414
Happy Valley	0.0461	0.5	43,835	5,396	33,259	54,412	0.2413
Ninilchik Bar	0.0753	1.0	71,574	9,249	53,445	89,702	0.2533
Ninilchik, Deep Creek to Lehmans[b]	0.3354	1.0	318,955	37,243	245,959	391,951	0.2289
Ninilchik, Lehmans to Access	0.0169	1.0	16,074	1,786	12,574	19,575	0.2178
Oil Pad Access	0.1607	1.0	152,788	20,737	112,143	193,433	0.2660
Clam Gulch, Tower to bluff	0.0992	1.0	94,334	12,499	69,837	118,832	0.2597
Clam Gulch, Bluff to A frame[b]	0.2381	1.0	226,442	28,620	170,347	282,538	0.2477
Clam Gulch, Bluff to S. Ext. of Cohoe Lp.	0.0112	1.0	10,624	1,642	7,405	13,843	0.3030
Cohoe	0.0036	0.5	3,388	780	1,858	4,917	0.4515
1990 Total Harvest =	950,974						
Variance of Total Harvest =	5,329,146,000						
1991							
Whiskey Gulch	0.0093	0.5					
Happy Valley	0.0541	0.5					
Ninilchik Bar	0.1158	1.0					
Ninilchik, Deep Creek to Lehmans[b]	0.3114	1.0					
Ninilchik, Lehmans to Access	0.0253	1.0					
Oil Pad Access	0.1544	1.0					
Clam Gulch	0.3239	1.0					
Cohoe	0.0057	0.5					

[a] Harvest estimates for the 1991 season will not be available until the fall of 1992.

[b] Study area.

Table 2. Harvest proportion[a] by beach area in the Cook Inlet eastside beach razor clam fishery adjusted for relative success rate, 1977-1991.

		Beach Area					
Year	No. of surveys	Cohoe	Clam Gulch	Oil Pad	Ninilchik	Happy Valley	Whiskey Gulch
1977	3	2.19	70.58	11.21	11.43	3.10	1.49
1978	9	1.78	74.73	10.37	6.91	4.32	1.89
1979	8	2.49	77.15	7.35	7.46	4.75	0.81
1980	8	1.97	67.45	8.22	11.71	8.33	2.31
1981	9	1.67	60.86	12.80	11.07	10.20	3.40
1982	6	1.19	49.56	10.94	13.71	18.36	6.23
1983	6	1.72	48.46	12.79	15.74	15.01	6.27
1984	6	0.92	45.73	19.48	20.17	10.03	3.67
1985	5	0.87	35.10	17.55	31.14	12.67	2.67
1986	4	1.00	25.32	21.44	35.45	13.31	3.47
1987	3	0.17	21.64	13.14	51.90	9.46	3.68
1988	3	0.75	26.14	4.86	53.33	11.22	3.70
1989	11	0.22	28.80	12.07	50.43	5.71	2.77
1990	12	0.36	34.85	16.07	42.76	4.61	1.36
Mean	7	1.24	47.60	12.73	25.94	9.36	3.12
1991	10	0.57	32.39	15.44	45.25	5.41	0.93

[a] Harvest proportions weighted by tidal height beginning in 1990.

Ninilchik beach, which contributed less than 100,000 clams to the total harvest in the late 1970s, first surpassed Clam Gulch in 1986 and has provided an estimated 398,755 to 624,607 clams annually since that time (Table 3).

Estimation of Age and Length Composition and Age-Specific Harvest by Beach

Age class composition of all razor clams sampled on eastside Kenai Peninsula beaches by beach and date in 1990 and 1991 is provided (Tables 4 and 5), although only the beaches of Clam Gulch and Ninilchik are being considered in this study. The dominant age class for the past 2 years on the Clam Gulch beach was age 8 (36.8% and 32.3%), while on Ninilchik beach age-3 (27.3% and 57.3%) clams were dominant. Although approximately 350 clams were dug from the Clam Gulch, Oil Pad, and Ninilchik beaches, the sampling goal of 300 specimens from each of these beaches was not achieved on Oil Pad or Ninilchik. The bleaching process weakens the shell and a greater number than expected were either broken in handling or determined to be unreliable by the researcher conducting the aging.

Reproductive success is variable on Kenai Peninsula beaches and major year classes may be followed in historic age composition tables. The 1977 year class on Clam Gulch first entered the fishery as age class 3 in 1980 and was the dominant year class during the years 1981 through 1984 (Table 6). The prominence of a year class on Ninilchik was most readily apparent for the 1981 year class which was dominant during the years 1984-1987 (Table 7).

Length-at-age information was an important component of the catch-at-age analysis as small razor clams were less vulnerable to the fishery than larger ones. Szarzi (1991) included only clams $\geq$ 80 mm in length in her catch-age analysis as this was the minimum size felt to be vulnerable to the fishery. Age-4 clams from Clam Gulch beach had attained this size in both 1990 and 1991 while harvestable size was attained at age 3 for Ninilchik beach (Table 8). Major year classes have historically first been prominent in the Clam Gulch fishery at age 4 or 5 and in the Ninilchik fishery at age 3 or 4 (Tables 6 and 7).

Estimated harvest by age class in 1991 for Clam Gulch, Oil Pad, and Ninilchik beaches and for the density study areas on Clam Gulch and Ninilchik beaches is presented in Table 9. Harvest was apportioned to ages 4 and older on the Clam Gulch and Oil Pad Beaches and to ages 3 and older on the Ninilchik Beach. Szarzi (1991) noted that the small sample sizes collected after 1981 were less than what was needed to produce a reliable population estimate. Sample sizes were increased for 1991. Harvest by age data needed to complete the catch-at-age analysis for Clam Gulch and Ninilchik are presented in Tables 10 and 11, respectively.

Estimation of Mean Density, Abundance, and Fishing Mortality

Szarzi conducted field sampling in 1990 to produce a density estimate for the Clam Gulch and Ninilchik study areas as well as for the Ninilchik bar. Results from her work along with the 1991 results are presented in Table 12. The density estimate in 1990 for the heavily harvested Ninilchik Bar (1.006 clams/m^2) was comparable to the estimate on the Ninilchik Beach study area (1.020 clams/m^2). These estimates on the beach study area in 1990 nearly doubled those in 1989 (0.582 clams/m^2) and the estimate in 1991

Table 3. Estimated harvest by beach area and participation in the Cook Inlet eastside beaches razor clam fishery, 1977-1990.[a]

Year	Beach Area						Total Harvest	Participation (Digger-Days)
	Cohoe	Clam Gulch	Oil Pad	Ninilchik	Happy Valley	Whiskey Gulch		
1977	19,072	614,943	97,684	99,545	26,979	13,025	871,247	25,393
1978	15,977	670,079	92,959	61,973	38,733	16,946	896,667	29,750
1979	24,023	745,767	71,025	72,070	45,958	7,834	966,677	30,323
1980	15,206	520,484	63,431	90,368	64,300	17,813	771,603	31,494
1981	13,864	504,833	106,130	91,788	84,617	28,206	829,436	31,298
1982	11,519	477,753	105,494	132,170	177,035	60,022	963,994	31,954
1983	16,854	474,312	125,199	154,091	146,868	61,396	978,720	31,470
1984	9,575	477,568	203,475	210,657	104,730	38,301	1,044,307	29,880
1985	9,312	374,943	187,472	332,731	135,327	28,555	1,068,340	31,195
1986	11,261	284,825	241,108	398,755	149,699	39,081	1,124,728	32,507
1987	1,664	211,890	128,687	508,092	92,632	36,055	979,020	25,427
1988	8,807	306,207	56,906	624,607	131,425	43,357	1,171,308	30,905
1989	1,809	239,697	100,401	419,696	47,487	23,065	832,155	22,658
1990	3,388	331,400	152,788	406,603	43,835	12,959	950,974	29,427
Mean	11,595	445,336	123,768	257,368	92,116	30,472	960,655	29,549

[a] Harvest and digger days of participation determined by Statewide Harvest Study. Harvest by beach is apportioned from aerial surveys and assumes a success rate of 0.5 on the Whiskey Gulch, Happy Valley, and Cohoe beach areas.

Table 4. Age class composition of razor clams sampled on Cook Inlet eastside beaches, 1990.

		Age Class													
		1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Cohoe	Number		11	7	90	3	2	12	1	1	1	1			129
Aug 9	Percent	0.00	8.53	5.43	69.77	2.33	1.55	9.30	0.78	0.78	0.78	0.78	0.00	0.00	
	SE	0.00	2.47	2.00	4.06	1.33	1.09	2.57	0.78	0.78	0.78	0.78	0.00	0.00	
Clam Gulch	Number	12	3	8	5	11	8	28	57	18	5				155
Jul 10	Percent	7.74	1.94	5.16	3.23	7.10	5.16	18.06	36.77	11.61	3.23	0.00	0.00	0.00	
	SE	2.15	1.11	1.78	1.42	2.07	1.78	3.10	3.89	2.58	1.42	0.00	0.00	0.00	
Oil Pad North	Number by age		11	13	19	6	18	14	28	7	1				117
Aug 7	Percent	0.00	9.40	11.11	16.24	5.13	15.38	11.97	23.93	5.98	0.85	0.00	0.00	0.00	
	SE	0.00	2.71	2.92	3.42	2.05	3.35	3.01	3.96	2.20	0.85	0.00	0.00	0.00	
Oil Pad South	Number by age		18	13	10	2	9	13	40	25	7				137
(Setnet Access)	Percent	0.00	13.14	9.49	7.30	1.46	6.57	9.49	29.20	18.25	5.11	0.00	0.00	0.00	
Jul 25	SE	0.00	2.90	2.51	2.23	1.03	2.12	2.51	3.90	3.31	1.89	0.00	0.00	0.00	
Oil Pad	Number by age	0	29	26	29	8	27	27	68	32	8	0	0	0	254
(Samples Combined)	Percent	0.00	11.42	10.24	11.42	3.15	10.63	10.63	26.77	12.60	3.15	0.00	0.00	0.00	
Jul 25	SE	0.00	2.00	1.91	2.00	1.10	1.94	1.94	2.78	2.09	1.10	0.00	0.00	0.00	
Ninilchik	Number by age		11	30	10	1	1	14	21	9	9	4			110
Jul 24	Percent	0.00	10.00	27.27	9.09	0.91	0.91	12.73	19.09	8.18	8.18	3.64	0.00	0.00	
	SE	0.00	2.87	4.27	2.75	0.91	0.91	3.19	3.76	2.63	2.63	1.79	0.00	0.00	
Deep Creek	Number by age		4	3	3	1	2								13
Jul 23	Percent	0.00	30.77	23.08	23.08	7.69	15.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	SE	0.00	13.32	12.16	12.16	7.69	10.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Table 5. Age class composition of razor clams sampled on Cook Inlet eastside beaches, 1991.

		Age Class													
		1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Cohoe	Number		1	43	51	6	2	4	3	4	1				115
Aug 13	Percent	0.00	0.87	37.39	44.35	5.22	1.74	3.48	2.61	3.48	0.87	0.00	0.00	0.00	
	SE	0.00	0.87	4.53	4.65	2.08	1.22	1.72	1.49	1.72	0.87	0.00	0.00	0.00	
Clam Gulch	Number			16	22	17	23	32	98	67	28				303
May 28	Percent	0.00	0.00	5.28	7.26	5.61	7.59	10.56	32.34	22.11	9.24	0.00	0.00	0.00	
	SE	0.00	0.00	1.29	1.49	1.32	1.52	1.77	2.69	2.39	1.67	0.00	0.00	0.00	
Oil Pad North	Number				6	15	12	20	34	29	10	5	2		133
May 19	Percent	0.00	0.00	0.00	4.51	11.28	9.02	15.04	25.56	21.80	7.52	3.76	1.50	0.00	
	SE	0.00	0.00	0.00	1.81	2.75	2.49	3.11	3.80	3.59	2.30	1.66	1.06	0.00	
Oil Pad South	Number			28	54	26		6	18	5	7	2			146
(Set Net Access)	Percent	0.00	0.00	19.18	36.99	17.81	0.00	4.11	12.33	3.42	4.79	1.37	0.00	0.00	
May 29	SE	0.00	0.00	3.27	4.01	3.18	0.00	1.65	2.73	1.51	1.77	0.97	0.00	0.00	
Oil Pad	Number	0	0	28	60	41	12	26	52	34	17	7	2	0	279
(Samples Combined)	Percent	0.00	0.00	10.04	21.51	14.70	4.30	9.32	18.64	12.19	6.09	2.51	0.72	0.00	
	SE	0.00	0.00	1.80	2.46	2.12	1.22	1.74	2.34	1.96	1.43	0.94	0.51	0.00	
Ninilchik Bar	Number			3	6	1	1	3	3	1	12	7		1	38
May 17	Percent	0.00	0.00	7.89	15.79	2.63	2.63	7.89	7.89	2.63	31.58	18.42	0.00	2.63	
	SE	0.00	0.00	4.43	5.99	2.63	2.63	4.43	4.43	2.63	7.64	6.37	0.00	2.63	
Ninilchik Bar	Number			57	3	1	4	21	7	10	13	1	1		118
Jul 12	Percent	0.00	0.00	48.31	2.54	0.85	3.39	17.80	5.93	8.47	11.02	0.85	0.85	0.00	
	SE	0.00	0.00	4.62	1.46	0.85	1.67	3.54	2.18	2.57	2.89	0.85	0.85	0.00	
Ninilchik	Number		2	55	8				1		1				67
North Beach	Percent	0.00	2.99	82.09	11.94	0.00	0.00	0.00	1.49	0.00	1.49	0.00	0.00	0.00	
Jul 12	SE	0.00	2.09	4.72	3.99	0.00	0.00	0.00	1.49	0.00	1.49	0.00	0.00	0.00	
Ninilchik	Number			43	7				2			1			53
South Beach	Percent	0.00	0.00	81.13	13.21	0.00	0.00	0.00	3.77	0.00	0.00	1.89	0.00	0.00	
Jul 11	SE	0.00	0.00	5.43	4.70	0.00	0.00	0.00	2.64	0.00	0.00	1.89	0.00	0.00	
Ninilchik	Number	0	2	158	24	2	5	24	13	11	26	9	1	1	276
(Samples Combined)	Percent	0.00	0.72	57.25	8.70	0.72	1.81	8.70	4.71	3.99	9.42	3.26	0.36	0.36	
	SE	0.00	0.51	2.98	1.70	0.51	0.80	1.70	1.28	1.18	1.76	1.07	0.36	0.36	
Happy Valley	Number			8	3				1		1				13
(Deep Creek)	Percent	0.00	0.00	61.54	23.08	0.00	0.00	0.00	7.69	0.00	7.69	0.00	0.00	0.00	
Aug 12	SE	0.00	0.00	14.04	12.16	0.00	0.00	0.00	7.69	0.00	7.69	0.00	0.00	0.00	

Table 6. Age class composition by percent of razor clams sampled at Clam Gulch beach, 1969-1991.

Year	Age Class 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Number Sampled
1969		2.4	5.8	13.6	5.4	36.5	36.3								742
1970			4.1	17.1	15.9	30.5	32.4								655
1971			0.9	28.8	17.6	29.0	20.2	3.5							688
1972				8.4	45.9	19.8	11.5	14.4							715
1973			1.5	2.4	8.6	52.4	23.3	9.2	2.6						824
1974			0.2	1.5	2.3	12.3	43.5	28.3	10.0	1.9					480
1975			0.4	0.6	4.2	5.0	18.6	42.9	19.2	9.1					504
1976				0.4	1.0	7.4	5.9	9.8	14.1	19.9	41.5				744
1977			1.1	3.0	2.0	4.5	5.9	8.8	28.9	45.8					433
1978				1.4	6.1	6.9	8.0	9.6	28.1	39.9					492
1979			0.2	1.5	5.3	5.3	9.5	11.2	30.0	30.0	6.2	0.8			546
1980		0.3	12.4	0.9	5.7	3.4	11.8	12.6	14.9	29.9	7.2	0.9			348
1981			0.4	30.9	14.3	8.5	10.0	7.7	5.8	17.4	4.2	0.8			260
1982		1.5	1.0	23.0	25.5	14.2	10.8	5.9	7.8	8.8	1.0	0.5			204
1983			4.3	5.1	16.3	36.8	17.9	6.8	2.6	7.6	1.7	0.9			116
1984		1.3	2.8	8.7	14.6	10.0	42.6	9.3	6.0	4.0		0.7			150
1985			3.1	7.7	9.2	6.2	30.8	16.9	6.2	12.3	4.6	1.5		1.5	65
1986			4.2	3.2	41.5	8.5	9.6	29.8	2.1	1.1					94
1987			19.3	3.7	18.3	38.6	12.8	6.4	0.9						109
1988				11.6	18.2	42.1	14.9	9.9	3.3						122
1989			2.7	10.7	2.7	24.1	21.4	18.8	11.6	8.0					112
1990	7.7	1.9	5.2	3.2	7.1	5.2	18.1	36.8	11.6	3.2					155
1991			5.3	7.3	5.6	7.6	10.6	32.3	22.1	9.2					303

Table 7. Age class composition by percent of razor clams sampled at Ninilchik beach, 1974 and 1977 to 1991.

Year	Age Class 2	3	4	5	6	7	8	9	10	11	12	13	Number Sampled
1974		1.3	1.3	1.3	43.0	21.5	22.2	9.4					149
1977				6.4	3.2	1.6	24.2	32.3	11.3	21.0			62
1978					12.5			37.5	12.5	25.0	12.5		8
1979													
1980		90.0	7.5	2.5									80
1981													
1982		7.5	5.0	3.1	79.5	1.2			2.5		1.2		161
1983	7.9	21.2	46.3	4.0	4.0	16.6							151
1984	1.4	63.0	27.4	6.8	1.4								73
1985		5.9	69.5	11.8	4.7	3.5	2.3	2.3					85
1986		3.4	3.4	48.9	34.1	3.4	5.7		1.1				88
1987		9.9	6.6	2.2	57.1	18.7	4.4	1.1					91
1988													
1989	4.8	0.7	7.6	16.5	6.2	1.4	22.1	24.8	9.7	4.1	1.4	0.7	145
1990	10.0	27.3	9.1	0.9	0.9	12.7	19.1	8.2	8.2	3.6			110
1991	0.7	57.3	8.7	0.7	1.8	8.7	4.7	4.0	9.4	3.3	0.4	0.4	276

Table 8. Mean length (millimeters) at last annulus formation by age class from selected Cook Inlet eastside beaches, 1990 and 1991.

		AGE CLASS													
1990		1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Clam Gulch	Number	12	3	8	5	11	8	28	57	18	5				155
	Mean length	25	38	74	83	106	111	116	118	121	122				
	SD	2	5	7	9	3	7	5	5	5	6				
Oil Pad	Number		29	26	29	8	27	27	68	32	8				254
	Mean length		41	72	90	100	119	123	126	130	135				
	SD		10	9	7	9	6	8	7	7	5				
Ninilchik	Number		11	30	10	1	1	14	21	9	9	4			110
	Mean length		65	84	101	98	137	138	143	147	151	157			
	SD		8	8	7	0	0	7	7	5	9	3			
		AGE CLASS													
1991		1	2	3	4	5	6	7	8	9	10	11	12	13	
Clam Gulch	Number			16	22	17	23	32	98	67	28				303
	Mean length			70	92	99	110	114	118	122	125				
	SD			5	5	5	5	5	5	6	5				
Oil Pad	Number			28	60	41	12	26	52	34	17	7	2		279
	Mean length			94	99	109	111	125	128	132	136	137	144		
	SD			5	6	5	3	5	5	5	6	4	3		
Ninilchik	Number		2	158	24	2	5	24	13	11	26	9	1	1	276
	Mean length		55	98	116	141	138	141	147	147	151	152	153	167	
	SD		1	10	5	5	4	5	8	6	6	4	0	0	

Table 9. Razor clam harvest by age class from selected Cook Inlet eastside beaches, 1990.

		Age Class													
		1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Clam Gulch	Number	12	3	8	5	11	8	28	57	18	5				155
	Percent	7.74	1.94	5.16	3.23	7.10	5.16	18.06	36.77	11.61	3.23	0.00	0.00	0.00	
	SE	2.15	1.11	1.78	1.42	2.07	1.78	3.10	3.89	2.58	1.42	0.00	0.00	0.00	
	Percent Age 4+				3.79	8.33	6.06	21.21	43.18	13.64	3.79	0.00	0.00	0.00	
	SE				1.67	2.41	2.08	3.57	4.33	3.00	1.67	0.00	0.00	0.00	
	Harvest				12,553	27,617	20,085	70,297	143,105	45,191	12,553	0	0	0	331,400
	SE				5,629	8,382	7,134	13,523	19,653	10,772	5,629	0	0	0	31,273
	Study Area				8,577	18,870	13,724	48,033	97,782	30,878	8,577	0	0	0	226,442
	SE				3,900	5,925	4,994	10,061	15,724	7,784	3,900	0	0	0	28,620
Oilpad	Number		29	26	29	8	27	27	68	32	8				254
	Percent	0.00	11.42	10.24	11.42	3.15	10.63	10.63	26.77	12.60	3.15	0.00	0.00	0.00	
	SE	0.00	2.00	1.91	2.00	1.10	1.94	1.94	2.78	2.09	1.10	0.00	0.00	0.00	
	Percent Age 4+				14.57	4.02	13.57	13.57	34.17	16.08	4.02	0.00	0.00	0.00	
	SE				2.51	1.40	2.43	2.43	3.37	2.61	1.40	0.00	0.00	0.00	
	Harvest				22,266	6,142	20,730	20,730	52,209	24,569	6,142	0	0	0	152,788
	SE				4,852	2,272	4,635	4,635	8,732	5,171	2,272	0	0	0	20,737
Ninilchik	Number		11	30	10	1	1	14	21	9	9	4	0	0	110
	Percent	0.00	10.00	27.27	9.09	0.91	0.91	12.73	19.09	8.18	8.18	3.64	0.00	0.00	
	SE	0.00	2.87	4.27	2.75	0.91	0.91	3.19	3.76	2.63	2.63	1.79	0.00	0.00	
	Percent Age 3+			30.30	10.10	1.01	1.01	14.14	21.21	9.09	9.09	4.04	0.00	0.00	
	SE			4.64	3.04	1.01	1.01	3.52	4.13	2.90	2.90	1.99	0.00	0.00	
	Harvest			123,213	41,071	4,107	4,107	57,499	86,249	36,964	36,964	16,428	0	0	406,603
	SE			22,105	12,918	4,107	4,107	15,248	18,596	12,263	12,263	8,200	0	0	38,416
	Study Area			101,524	33,841	3,384	3,384	47,378	71,067	30,457	30,457	13,537	0	0	335,029
	SE			19,146	10,812	3,384	3,384	12,851	15,862	10,246	10,246	6,792	0	0	37,286

Table 10. Estimated razor clam harvest by age class from Clam Gulch beach, 1977-1990.

Year	Age Class 4	5	6	7	8	9	10	11+	Total
1977	18,653	12,436	27,980	36,685	54,717	179,695	284,777		614,943
1978	9,381	40,875	46,235	53,606	64,328	188,292	267,362		670,079
1979	11,209	39,605	39,605	70,990	83,693	224,178	224,178	52,308	745,767
1980	5,366	33,984	20,271	70,352	75,121	88,834	178,264	48,292	520,484
1981	156,620	72,481	43,083	50,686	39,028	29,398	88,194	25,343	504,833
1982	112,701	124,951	69,580	52,920	28,910	38,220	43,120	7,350	477,753
1983	25,277	80,787	182,390	88,717	33,702	12,886	37,667	12,886	474,312
1984	43,325	72,706	49,799	212,142	46,313	29,879	19,919	3,486	477,568
1985	29,794	35,598	23,990	119,177	65,393	23,990	47,593	29,407	374,943
1986	9,514	123,385	25,272	28,542	88,599	6,244	3,270		284,825
1987	9,715	48,049	101,350	33,608	16,804	2,363			211,890
1988	35,520	55,730	128,913	45,625	30,314	10,105			306,207
1989	26,359	6,651	59,370	52,719	46,313	28,576	19,708		239,697
1990	12,553	27,617	20,085	70,297	143,105	45,191	12,553		331,400

Table 11. Estimated razor clam harvest by age class from Ninilchik beach, 1977-1990.

	Age Class									
Year	3	4	5	6	7	8	9	10	11+	Total
1977			6,371	3,185	1,593	24,090	32,153	11,249	20,904	99,545
1978				7,747			23,240	7,747	23,240	61,973
1979										72,070
1980	81,331	6,778	2,259							90,368
1981										91,788
1982	9,913	6,609	4,097	105,075	1,586			3,304	1,586	132,170
1983	35,469	77,464	6,692	6,692	27,773					154,091
1984	134,598	58,540	14,528	2,991						210,657
1985	19,631	231,248	39,262	15,638	11,646	7,653	7,653			332,731
1986	13,558	13,558	194,991	135,975	13,558	22,729		4,386		398,755
1987	50,301	33,534	11,178	290,121	95,013	22,356	5,589			508,092
1988										624,607
1989	3,086	33,505	72,741	27,333	6,172	97,429	109,333	42,763	27,333	419,696
1990	123,213	41,071	4,107	4,107	57,499	86,249	36,964	36,964	16,428	406,603

Table 12. Density, population and exploitation estimates of harvestable[a] clams in selected study areas on Clam Gulch and Ninilchik beaches, 1988-1991.

Beach	Year	Area (m^2)	Clams/m^2	SE	Population Estimate	SE	Relative Precision[b]	Harvest	% Harvested
Clam Gulch	1988	1,513,357	3.973	0.643	6,012,018	973,089	0.2075		
Clam Gulch	1989	1,513,357	2.050	0.295	3,102,703	446,440	0.1844		
Clam Gulch	1990	1,513,357	2.043	0.169	3,092,000	255,757	0.1060	226,442	7.32
Ninilchik	1988	1,108,435	0.894	0.308	990,941	341,398	0.4416		
Ninilchik	1989	1,108,435	0.582	0.300	645,109	332,531	0.6607	351,586	54.50
Ninilchik	1990	1,108,435	1.020	0.384	1,131,025	425,639	0.4823	318,955	28.20
Ninilchik Bar	1990		1.006	0.319				71,574	
Ninilchik	1991	1,108,435	1.595	0.432	1,768,286	478,898	0.3461		

[a] Clams 80 mm or greater in length are considered to be harvestable.

[b] 80% confidence interval.

(1.595 clams/m^2) was 56% greater than the 1990 estimate. This population increase can be accounted for by the large increase in age-3 clams in both 1990 and 1991. The density estimate for the Clam Gulch study area in 1990 (2.043 clams/m^2) approximated the 1989 estimate (2.050 clams/m^2). While relative precision for the 1991 Ninilchik estimate has improved over prior years it was still high at 34.6%.

Counts of diggers were not separated between the study area and the remainder of the Clam Gulch beach in 1988 or 1989 nor the Ninilchik study area from the remainder of that beach in 1988 preventing harvest apportionment to those study areas. Annual exploitation on Clam Gulch beach in 1990 was 7.3%. The Ninilchik study area exploitation estimate for 1989 was 54.5%, declining to 28.2% in 1990.

Instantaneous fishing mortality (F) for Clam Gulch was estimated at:

Year	F
1988	0.055671
1989	0.085677
1990	0.081038

Catch-at-Age Analysis

Exploitable abundance of razor clams on Clam Gulch beach as estimated by catch-at-age analysis ranged from 935,860 clams in 1982 to 4,150,280 clams in 1990 (Table 13). The fractions of each partially recruited age class available to the Clam Gulch fishery were estimated at:

Age	Fraction
4	0.2110
5	0.3154
6	0.3675

Age-7 and older clams were estimated to be fully recruited to the Clam Gulch fishery.

Total abundance of razor clams on Clam Gulch beach ranged from 2,004,178 in 1980 to 6,917,050 in 1990 (Table 14). Temporal trends in abundance were evident. During the period 1981 to 1984, abundance was stable at approximately 2.4 million clams. Abundance has steadily increased since 1985 to approximately 6.9 million clams in 1990. Relative precision of the estimates remained stable at approximately 25% (α = 0.80) through 1985. Relative precision for estimates since 1986 has steadily decreased to 42%. As expected in this type of modeling, confidence in the most recent estimate is low.

The absence of data in 1979, 1981, and 1988 from Ninilchik precluded catch-at-age analysis for this beach.

Table 13. Estimated abundance of exploitable razor clams age 4 and older on Clam Gulch beach, 1977-1990.

	Abundance by Age									
Year	4	5	6	7	8	9	10	11+	Total	SE
1977	73,570	49,049	110,357	144,690	215,811	708,740	1,123,197		2,425,414	590,790
1978	29,861	130,111	147,173	170,636	204,766	599,363	851,055		2,132,965	491,956
1979	23,913	84,492	84,492	151,449	178,549	478,256	478,256	111,593	1,591,003	364,875
1980	12,522	79,303	47,303	164,169	175,297	207,297	415,985	112,691	1,214,567	273,942
1981	308,664	142,844	84,907	99,891	76,916	57,937	173,811	49,946	994,917	216,898
1982	220,768	244,764	136,299	103,664	56,631	74,868	84,467	14,398	935,860	200,585
1983	50,518	161,458	364,519	177,307	67,356	25,754	75,280	25,754	947,945	213,185
1984	102,544	172,085	117,867	502,113	109,616	70,719	47,145	8,208	1,130,336	265,534
1985	98,394	117,561	79,226	393,578	215,958	79,226	156,844	97,115	1,238,235	308,688
1986	47,912	621,357	127,268	143,735	446,178	31,444	16,467		1,434,356	368,673
1987	92,411	457,053	964,064	319,687	159,843	22,477			2,015,545	432,952
1988	331,109	519,502	1,201,696	425,305	282,580	94,196			2,854,389	556,571
1989	403,468	101,805	908,756	806,951	708,897	437,403	301,664		3,668,959	724,799
1990	157,207	345,861	251,534	880,363	1,792,172	565,948	156,957		4,150,280	849,679

Table 14. Estimated abundance of razor clams age 4 and older on Clam Gulch beach, 1977-1990.

	Abundance by Age									
Year	4	5	6	7	8	9	10	11+	Total	SE
1977	403,906	180,150	347,860	167,611	249,998	821,013	1,301,125	0	3,471,663	658,146
1978	151,770	442,400	429,470	182,992	219,593	642,763	912,681	0	2,981,670	556,035
1979	138,359	327,047	280,682	184,892	217,977	583,868	583,868	0	2,452,929	453,039
1980	78,510	332,636	170,284	217,186	231,909	274,243	550,326	140,573	2,004,178	353,404
1981	1,354,487	419,346	213,924	92,491	71,217	53,645	160,934	223,819	2,412,289	416,876
1982	1,025,815	760,855	363,623	101,635	55,523	73,403	82,814	124,387	2,477,784	463,627
1983	264,507	565,555	1,095,818	195,885	74,413	28,452	83,168	35,942	2,336,250	456,883
1984	560,539	629,300	369,924	579,133	126,431	81,567	54,377	65,494	2,410,738	463,216
1985	781,743	624,858	361,402	659,797	362,034	132,815	262,934	24,315	3,348,388	666,380
1986	323,053	2,802,812	492,692	204,493	634,778	44,736	23,428	354,976	4,525,992	1,043,163
1987	465,600	1,540,549	2,788,812	339,856	169,928	23,896	0	0	5,328,642	1,257,376
1988	1,256,312	1,318,665	2,617,860	340,494	226,230	75,412	0	0	5,834,973	1,376,569
1989	1,857,065	313,477	2,401,543	783,696	688,468	424,798	292,970	0	6,762,018	1,704,287
1990	870,317	1,280,935	799,516	1,028,370	2,093,472	661,096	183,344	0	6,917,050	2,271,598

DISCUSSION

Szarzi (1991) presented a population estimate for the entire Clam Gulch beach for 1988 of 14,068,902 harvestable clams which is more than double this CAGEAN estimate of 5,834,973. Total clam abundance on Clam Gulch beach as estimated by on-site survey in 1988 was 6,012,018 clams, similar to the most recent CAGEAN estimate. As mentioned earlier, caution should be taken with the most recent estimates. Estimates for these most recent years will continue to change as sampling in future years provides a more complete picture of the strength of cohorts which have just entered the fishery. Density estimates conducted on a periodic basis provide managers not only with current information but a means to evaluate and modify the catch-at-age analysis.

While the CAGEAN analysis indicates that the clam population at Clam Gulch declined in the early 1980s and has been on the increase since 1985, caution should be exercised in placing emphasis on specific numbers. Not only were sample sizes for age composition quite low in the middle years of this analysis, but aerial surveys to apportion harvest by beach were minimal in some years.

Stock assessment for Clam Gulch beach is as follows. Total clam abundance on Clam Gulch beach as estimated by on-site surveys in 1990 was 3,092,000 clams. Clam abundance on Clam Gulch beach remained stable since 1989, annual exploitation was low (7.3%), and recruitment of age-3 clams was low (2.7% and 5.2% in 1989 and 1990, respectively). Population estimates from catch-at-age analysis revealed increased abundance of age-4 and older clams from population levels during the mid-1980s.

Stock assessment for Ninilchik beach is as follows. Estimated clam density on Ninilchik beach in 1991 (1.595 clams/m^2) was greater than the 1990 estimate (1.020 clams/m^2). Total abundance in 1991 was estimated at 1,768,286 clams. This increase in abundance is likely due to high levels of recruitment of age-3 clams. Estimated exploitation on Ninilchik beach during 1990 was high (54.5%). However, exploitation during 1991, using a preliminary harvest estimate, was 17.6%.

Resource managers have had few concerns in recent years regarding the effect of harvest on the Clam Gulch razor clam population which was further confirmed by the estimated exploitation rate of 7.32% in 1990. An exploitation rate of 54.5% on the Ninilchik beach in 1990, however, suggests that abundance on specific beach locations might be impacted by the current levels of harvest. The 1991 harvest estimate is not yet available. However, by making a preliminary estimate of 1,000,000 clams harvested on the eastside beaches in 1991, the estimated harvest on Ninilchik would be 311,400 for an exploitation rate of 17.6%. Managers have some comfort in the fact that as clam populations changed, digger effort in the past has simply shifted to more productive beaches. Additionally, this effort is concentrated around a few access points leaving miles of relatively unexploited beach in between. The accelerated growth rate on the more southern beaches leading to the availability of clams of a larger size than at Clam Gulch is felt to be the primary factor contributing to the shift of digger effort to the readily accessible Ninilchik beach (Figure 5). While it is assumed that the powerful Cook Inlet tides will carry razor clam spawn many miles up and down the

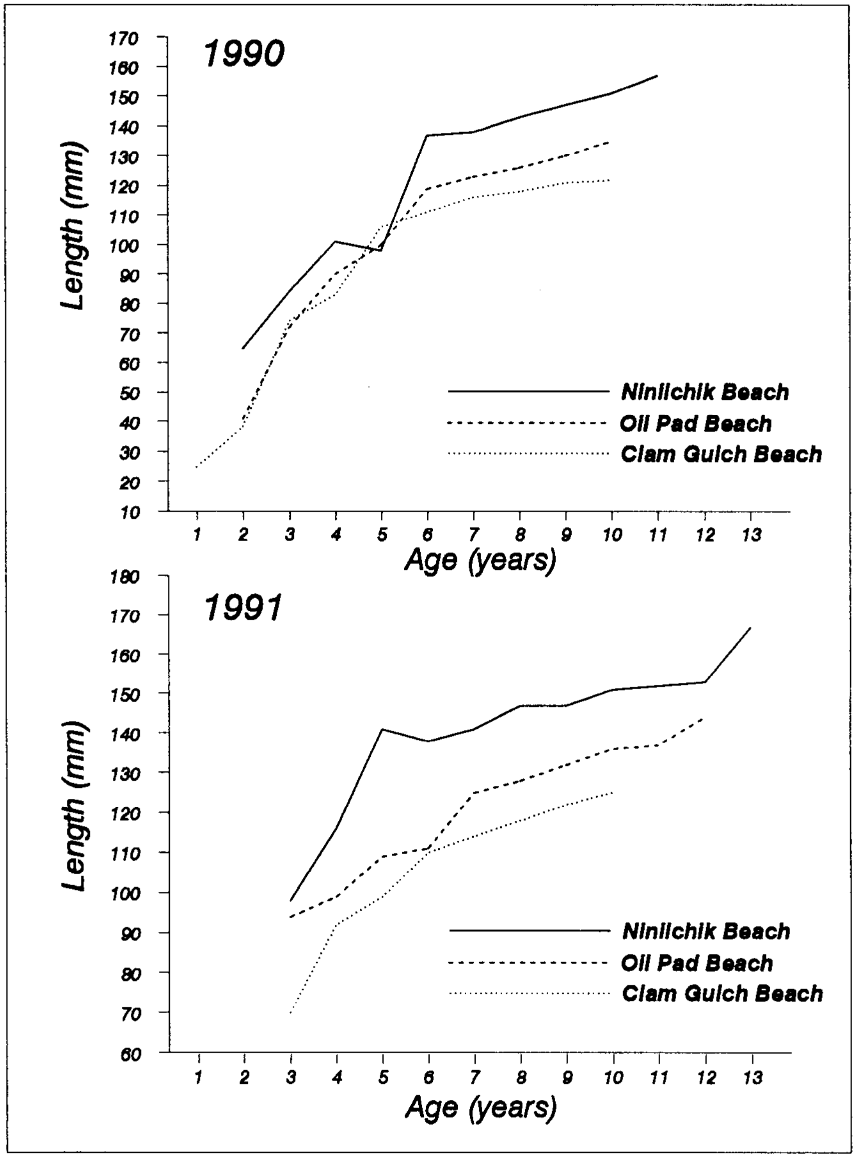

Figure 5. Mean length at age of razor clams sampled from three Kenai Peninsula beaches, 1990 and 1991.

eastside beaches, we do not know how important local populations are to the repopulation of specific beaches.

RECOMMENDATIONS

As the catch-at-age analysis is based on age composition of harvested razor clams, it is imperative that aging techniques be consistent and desirable that they be accurate. I have concerns regarding the consistency of our aging techniques as the task of aging gets passed from researcher to researcher over time. I am even concerned about my own ability to maintain consistency over subsequent seasons with changing growth patterns from one year to the next. In an attempt to address this problem, I have saved representative specimens from each year class of the 1991 samples by beach so that year classes can be compared to samples in subsequent years. I recommend that this practice be continued in future years. Growth rates are variable enough between years that definite patterns do emerge. The primary questions regarding accuracy concern the first 2 years of life. To address this concern, a life history study has been proposed that would focus on the early life history of Cook Inlet razor clams.

ACKNOWLEDGMENTS

Mary King coordinated and participated in the collection of specimens for aging and conducted the aging and preliminary data analysis of those specimens. Patricia Berkhahn assembled and maintained sampling equipment as well as served as crew leader for the density sampling segment of the project. Pamela Pomeroy, John Roemer, Laurie Stuart, and Lowell Fair conducted density sampling as well as collected samples for aging. Marianna Alexandersdottir, Sandy Sonnichsen, and Dave Bernard of the RTS staff provided assistance with project planning, data analysis, and report preparation. Dave Nelson provided encouragement and valuable insight gained from his many years of research on Kenai Peninsula clam beaches.

LITERATURE CITED

Deriso, R. B., T. J. Quinn II, and P. R. Neal. 1985. Catch-at-age analysis with auxiliary information. Can. J. Fish. Aquat. Sci. 42:815-824.

Deriso, R. B., P. R. Neal and T. J. Quinn II. 1989. Further aspects of catch-at-age analysis with auxiliary information. Pages 127-135 *in* R. J. Beamish and G. A. McFarlane, editors. Effects of ocean variability on recruitment and evaluation of parameters used in stock assessment models. Can. J. Fish. Aquat. Sci. Spec. Pub. 108.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20 (SW-1-A), Juneau.

______. 1980. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21 (SW-1-A), Juneau.

______. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A), Juneau.

______. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A), Juneau.

______. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23 (SW-1-A), Juneau.

______. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24 (SW-1-A), Juneau.

______. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25 (SW-1-A), Juneau.

______. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26 (SW-1-A), Juneau.

______. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27 (RT-2), Juneau.

______. 1987. Alaska statewide sport fisheries harvest report 1986. Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

______. 1988. Alaska statewide sport fisheries harvest report 1987. Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

______. 1989. Alaska statewide sport fisheries harvest report 1988. Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau.

______. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage.

______. 1991. Harvest and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage.

Nelson, D. C. *Unpublished.* A review of Alaska's Kenai Peninsula east side beach recreational razor clam fishery, 1965-1980. Alaska Department of Fish and Game, Division of Sport Fish, Soldotna, Alaska.

______. *Unpublished.* Kenai Peninsula management report, 1990. Alaska Department of Fish and Game, Division of Sport Fish, Soldotna, Alaska.

Quinn, T. J. and N. F. Jones. 1989. Razor clam (*Siliqua patula*, Dixon) investigations on the eastside Cook Inlet beaches. Project Report UAF-JCFOS-8902. Juneau Center for Fisheries and Ocean Sciences, University of Alaska, Fairbanks.

Szarzi, N. J. 1991. Distribution and abundance of the Pacific razor clam, *Siliqua patula* (Dixon), on the east side Cook Inlet beaches. Master's thesis, University of Alaska, Fairbanks.

Wolter, K. M. 1985. Introduction to variance estimation. Springer-Verlag, New York, New York.

APPENDIX A

Razor Clam Digger Counts on Cook Inlet Eastside Beaches

Appendix A1. Razor clam digger counts on Cook Inlet eastside beaches, 1990.

Date:	4/29/90	5/23/90	5/28/90	6/12/90	6/19/90	6/24/90	7/08/90	7/19/90	7/21/90	7/24/90	8/8/90	8/20/90
Tide:	-2.4	-4.1	-3.0	-0.9	-0.4	-3.7	-1.8	-1.3	-3.1	-3.7	-2.0	-3.1
1. Whiskey Gulch												
Anchor River to Happy Creek	10	36	18	0	0	81	1	0	51	18	0	6
2. Happy Valley												
Happy Creek to Deep Creek	12	123	23	0	0	173	25	2	170	50	23	22
3. Ninilchik												
Deep Creek to Set Net Access	130	240	159	9	12	682	140	57	416	197	66	146
A. Ninilchik Bar	25	77	3	0	0	208	9	0	165	64	4	17
B. Dp.Ck. to Lehmans (beach)	99	157	143	9	12	448	129	53	245	114	60	112
C. Lehmans to Access	6	6	13	0	0	26	2	4	6	19	2	17
4. Oil Pad Access												
Set Net Access to C. G. Tower	57	39	41	17	3	215	72	12	85	44	28	66
5. Clam Gulch												
Tower to S. Ext. of Cohoe Lp. Rd.	189	79	122	31	20	368	100	37	187	76	53	110
A. Tower to bluff	30	13	23	4	0	206	30	7	55	28	33	54
B. Bluff to A frame	152	62	94	27	20	157	70	27	108	38	20	51
C. Bluff to S. Ext. of Cohoe Lp.	7	4	5	0	0	5	0	3	24	10	0	5
6. Cohoe												
S. Ext. of Cohoe Lp. Rd to Kas. R.	0	0	0	0	0	9	0	0	0	2	9	7

Appendix A2. Razor clam digger counts on Cook Inlet eastside beaches, 1991.

Month:	5	6	6	6	7	7	7	7	7	8
Day:	30	12	16	27	13	14	15	27	28	14
Time:	11:35	10:10	13:15	10:40	11:15	12:05	12:45	10:45	11:15	10:20
Tide:	-1.7	-5.0	-3.6	-1.6	-5.5	-4.7	-3.2	-1.5	-1.5	-4.6
1. Whiskey Gulch										
Anchor River to Happy Creek	0	54	15	0	97	33	14	0	0	32
2. Happy Valley										
Happy Creek to Deep Creek	10	126	35	8	284	175	96	39	30	186
3. Ninilchik										
Deep Creek to Set Net Access	14	435	324	95	1057	720	187	156	131	851
A. Ninilchik Bar	0	180	105	4	399	322	51	5	5	387
B. Dp.Ck. to Ninilchik River	3	141	50	30	203	118	40	85	47	120
C. Ninilchik River to Lehmans	9	92	147	40	404	265	79	66	74	307
D. Lehmans to Access	2	22	22	21	51	15	17	0	5	37
4. Oil Pad Access										
Set Net Access to C. G. Tower	10	45	102	39	247	165	67	80	76	170
5. Clam Gulch										
Tower to S. Ext. of Cohoe Lp. Rd.	16	219	147	98	437	327	150	189	136	336
6. Cohoe										
S. Ext. of Cohoe Lp. Rd to Kas. R.	0	2	5	0	26	22	6	4	8	17